Mining Geothermal Resources

Adam Wallace (former Livermore employee and now a Ph.D. candidate at Virginia Polytechnic Institute) keeps an eye on the 19-liter stirred reactor used to test silica precipitation in Livermore's mobile laboratory at the Mammoth Pacific LP geothermal power plant in Mammoth Lakes, California.

IT'S beautiful on beaches and receives kudos for its use in paint, tires, paper, toothpaste, and even in kitty litter—but it's a real pain in geothermal power plants. It's silica, and 6 million pounds of it is refined from beach sand every day and used to extend the life of tires and soles of shoes, to control the physical properties of paint, to increase the opacity and improve the adhesion of ink to paper, and much more. Unfortunately, in geothermal power plants, as a component of the heated underground fluids, silica clogs pipes, wells, and heat exchangers.

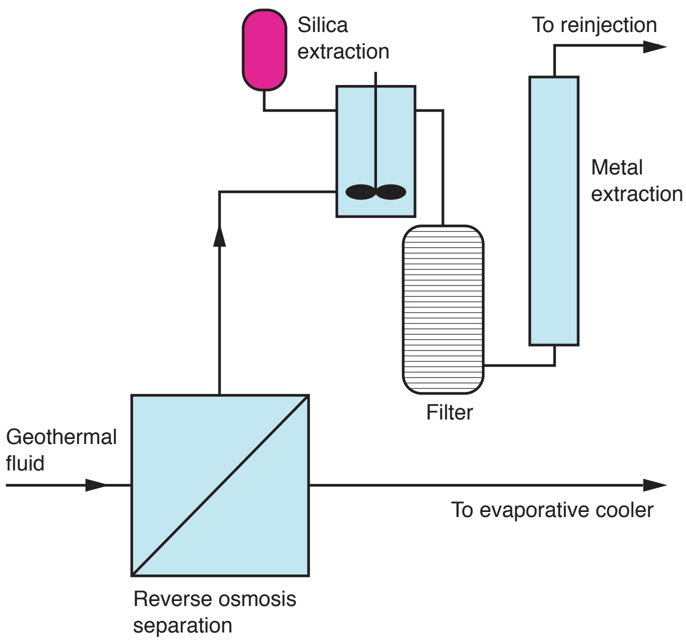
Lawrence Livermore has developed a technology for extracting silica from geothermal fluids, allowing plants to work more efficiently and have a marketable silica by-product. Once the silica is removed, the door is open to mining other metals from the geothermal brine as well, including lithium (used in ceramics and batteries) and tungsten. Another benefit to silica extraction is the production of freshwater that can be used as a heat exchanger coolant to further increase power production.

A New Bonanza?

The silica-mining story got a big boost three years ago when the California Energy Commission staff suggested to Livermore geochemists Bill Bourcier and Carol Bruton that it would be advantageous to find a way to extract lithium from geothermal resources. On the commercial market, a pound of lithium commands as much as $2.50. Some geothermal systems bring to the surface and then reinject over 50 metric tons of lithium per day, which means a mineral by-product worth upward of $500 million per year is being thrown away.

"Before considering lithium extraction," says Bourcier, "we had to deal with the silica in the geothermal fluid, which clogs up tanks, pipes, and other equipment. Finding a way to extract silica from the fluid is key to this type of 'cascaded use' of geothermal energy—that is, extracting not only heat for energy but also marketable by-products, such as silica and other minerals, for resale."

In 2002, Livermore scientists were able to pursue this concept when they were awarded a $669,683 grant from the California Energy Commission's (CEC's) Public Interest Energy Research (PIER) Program with cofunding from the Department of Energy's Geothermal Technologies Program. Livermore and Mammoth Pacific LP formed an agreement allowing the scientists to conduct their research at the geothermal power plant in Mammoth Lakes, California.

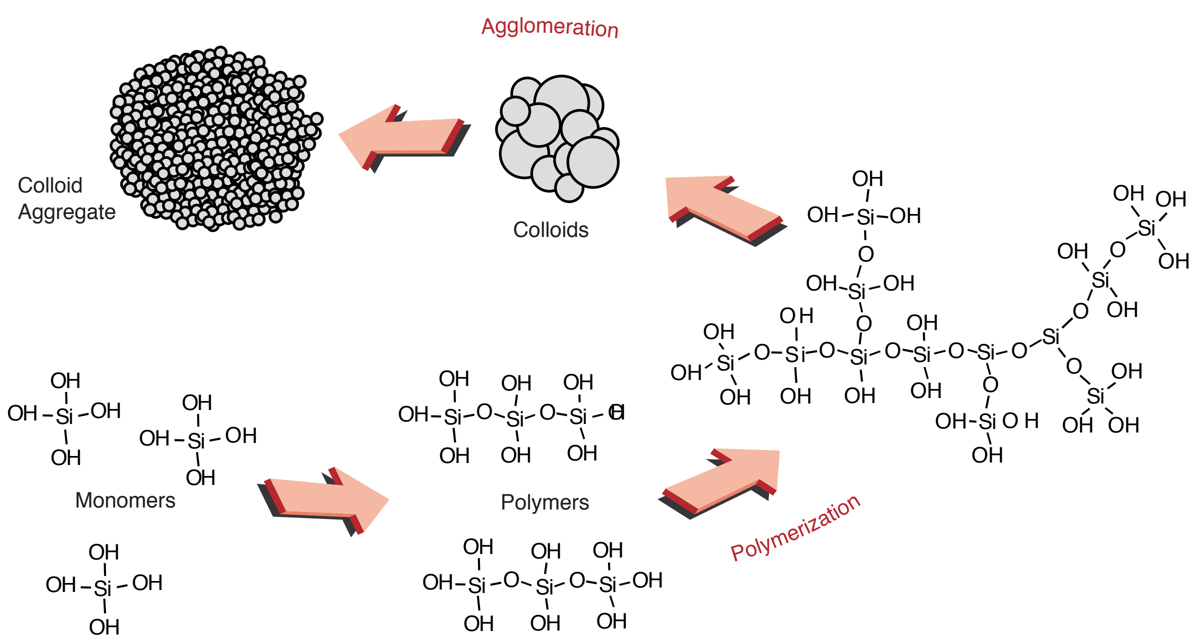


The Livermore extraction process involves running a geothermal fluid through a reverse-osmosis separation process to create freshwater and concentrated brine. The freshwater is used for evaporative cooling, and the concentrated brine is pumped into a reactor where chemicals are added and silica is extracted. The silica-free brine can then be pumped through another process for extraction of other metals before the fluid is pumped to a surface pond and reinjected into the subsurface.

"Power plant managers wanted freshwater for cooling and a silica by-product that could be resold," says program leader Bruton. "Production of marketable by-products reduces the cost of geothermal power, which is a goal of the CEC's PIER Program. Mammoth Pacific was willing to let us come test our process at their facility in return for our results. With these results, their managers could evaluate the economic benefits of full-scale implementation. So we set up a small field station and mobile laboratory at the geothermal plant for our experiments."

The Livermore-developed extraction process begins with geothermal fluid obtained upstream from the power plant's air-cooled heat exchangers. The silica is concentrated in the fluid using reverse osmosis—the same process used at water treatment plants to purify water. (See the box p. 27.) The concentrated fluid then flows through a stirred reactor where salts or polyelectrolytes are added to induce silica precipitation. The simple silica molecules bond together to form colloids—silica particles about 10 to 100 nanometers in size. These larger molecules cluster to form particles that can be removed by filters downstream from the reactor.

The scientists discovered that the properties of the silica can be varied by changing the silica's residence time in the reactor, varying the pH of the fluid, changing the amounts of additives, and changing the silica concentration. The variables interrelate—for example, shorter residence times produce smaller silica particles that are more difficult to filter but are of higher value. Longer residence times and higher additive concentrations



The Livermore extraction process allows scientists to control the size of colloids and agglomerates so that their surface areas and pore sizes match those of commercially useful silicas. The compound involved consists of silicon (Si) atoms surrounded by hydroxyl (OH) groups composed of oxygen and hydrogen.

produce more firmly agglomerated particles that are relatively easy to filter but less suited to high-end commercial applications. Bourcier notes, “The properties of the silica must match the particular market needs. For instance, the size of the silica clusters and the silica purity are important when silica is used to increase rubber lifetime or as a polishing agent for silicon wafers in the electronics industry.”

Presently, the Livermore scientists can produce silica with a purity of greater than 99 percent and surface areas ranging from 50 to 150 square meters per gram. In addition, the water obtained from the reverse-osmosis process has less than 100 parts per million total salt and less than 20 parts per million silica, making it ideal for cooling applications at the power plant.

Minerals for the Mining Industry

The market value of silica that could potentially be produced from the Mammoth plant is about $10 million per year, based on both the typical market price of 70 cents per pound for precipitated silica used in rubber manufacturing and a recovery rate of 7,200 tons per year. For the process that treats and extracts silica from the entire fluid stream, a preliminary economic evaluation suggests the equipment would be paid for in 7 years, and the rate of return on the investment would be about 16 percent.

To date, the researcher’s work has focused on silica extraction, but extracting other mineral by-products, including lithium, is not far behind. “Many other metals could be ‘mined’ at Mammoth,” says Bourcier. “In addition to lithium, the geothermal fluid contains tungsten and two materials with no other known sources in the U.S.—cesium and rubidium.”

The silica extraction project has been funded by the CEC at $737,000 for the next steps, which are to conduct a continuous pilot-scale process test and an economic analysis of the results. “So far, so good,” says Bruton. “For Mammoth Pacific, we’ve developed an extraction process for silica, and a source of clean water for cooling. For the geothermal industry as a whole, we’ve found a way to create a new geothermal revenue stream through mineral extraction and a methodology for making silica with tailored properties. Other U.S. industries can look forward to a source of low-cost silica as well as a domestic and ‘green’ source for other metals.”

—Ann Parker

Key Words: cascaded use, geothermal energy, geothermal mining, Mammoth Lakes, silica extraction.

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Reverse Osmosis

Normal osmosis occurs when water from a solution of lower solute concentration is moved across a membrane to a solution of higher solute concentration. For example, if a semipermeable membrane has freshwater on one side and a concentrated saltwater solution on the other side, during normal osmosis the freshwater will cross the membrane to dilute the concentrated solution.

In reverse osmosis, pressure is exerted on the side with the concentrated solution to force the water molecules across the membrane to the freshwater side. Reverse osmosis is often used in commercial and residential water filtration and to desalinate seawater.